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IMPACT OF COOPERATION IN IRRIGATION WATER MANAGEMENT ON TECHNICAL EFFICIENCY AND IRRIGATION WATER EFFICIENCY OF SMALLHOLDERS IN LEBANON

by
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AN ABSTRACT OF THE THESIS OF

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Title: Impact of Cooperation in Irrigation Water Management on Technical Efficiency and Irrigation Water Efficiency of Smallholders in Lebanon.

Lebanon is relatively rich in water resources in the Middle East and North Africa. However, in recent years, Lebanon was faced with drastic decrease in crop yield due to shortage of accessible water. Agriculture in Lebanon mostly consists of small and fragmented land farms, which hampers efficient large scale irrigation. Cooperation among farmers has been one way which farmers could hope to increase their overall as well as irrigation efficiencies.

The objectives of this study are 1) to measure technical efficiency of farmers, especially smallholders, in Lebanon and identify determinants of their inefficiency using stochastic frontier analysis, 2) to measure irrigation water efficiency and identify factors affecting it, especially, the impact of participation in farmers' groups and associations, and 3) to draw policy recommendations based on these efficiency estimates.

The estimated stochastic frontier production function suggested the prevalence of significant technical inefficiency. The mean estimated technical efficiencies of fruit tree and vegetable farms are 62.93 percent and 60.87 percent, respectively. The mean estimated irrigation water efficiencies of fruit tree and vegetable farms are 15.14 percent and 39.38 percent, respectively. There is therefore ample room for increasing crop yields while maintaining the current input levels.

While participation in farmers' group for irrigation water management does not significantly affect technical inefficiency of fruit tree farms, it significantly reduces the technical inefficiency of vegetable farms and significantly increases irrigation water efficiency of both fruit tree and vegetable farms. For both fruit tree and vegetable farms, the adoption of surface irrigation significantly and greatly increases technical inefficiency and decreases irrigation water efficiency.

Smallholders in the region who are members of farmers' groups also show higher technical efficiency and irrigation efficiency though the size of total irrigated area significantly decreases technical inefficiency of fruit tree farms and increases irrigation water efficiencies. This is because the coefficient of participation to farmers' group is much higher than that of total irrigated areas. Thus, participation to farmers' groups and associations can greatly contribute to increasing irrigation water efficiency of smallholders.

Based on the insights this analysis, policies to encourage formation of farmers' group for irrigation water management and water saving irrigation method, in place of surface irrigation, should be required in order to increase technical and irrigation water efficiency.

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LIST OF ABBREVIATIONS

DEA: Data Envelopment Analysis

LC: Local Water Committees

LRA: Litani River Authority

MoEW: Ministry of Energy and Water

RWA: Regional Water Authorities

SFA: Stochastic Frontier Analysis

WA: Water Authority

WUA: Water Users' Association

CHAPTER 1

INTRODUCTION

Sustainable supply of water is indispensable for high crop productivity. Especially, in arid or semi-arid areas, irrigation water management is a crucial issue since agriculture sector is the largest consumer of water. A recent study indicates that the water balance in Lebanon will have a water deficit within the next two decades (El-Fadel *et al*. 2010).

Recently, the agriculture sector of Lebanon faced a drastic decrease of crop yields. Assessment of FAO (2015) shows that 42 percent of crops are yielding less than 50 percent of what they did 24 months ago. Farmers mentioned the reasons were attributed to the reduction in accessible water, due to precipitation shortage and pollution of water sources. Uncontrolled use of groundwater for agriculture, especially in dry years, leads to lowering of water table and decrease of water quality with increase of salinity (Baasiri and Ryan 1986; Ministry of Agriculture 2003). In addition, the use of fertilizers and pesticides are poorly regulated and monitored in Lebanon, which leads to ground water pollution by agro-chemicals (World Bank 2003). The situation surrounding agriculture, such as climate change and availability of water, have been changing drastically and many smallholders are faced with adopting with the radical changes. Water scarcity is currently becoming a main factor of limiting the expansion of agricultural production in Lebanon.

Agricultural production in Lebanon faces many challenges. The most crucial problem is the high production cost structure and limited competitiveness (CDR 2015). This is mainly attributed to small and fragmented farm lands and traditional wasteful irrigation practices such as furrow irrigation in many areas, in addition to the high usage of fertilizers and pesticides that are encouraged by input suppliers (Ministry of Agriculture 2003; World Bank 2003). Increase in water scarcity also raises agricultural production costs due to need to purchase water for irrigation (FAO 2015). Agriculture in Lebanon mostly consists of small and fragmented farms, which hampers efficient large scale irrigation. In addition, very low adoption rate of water saving technologies leads to low irrigation water efficiency (World Bank 2003). High irrigation efficiency requires technical know-how and proper management skills (Ministry of Agriculture 2003). Many smallholders are facing financial and material restrictions to invest in and manage modern irrigation systems. However, cooperation among smallholders can enhance irrigation water use efficiency to overcome those restrictions. Therefore, this study analyzes the impacts of cooperation among smallholders in Lebanon on technical efficiency and irrigation water efficiency of farming across a variety of cropping systems.

The objectives of this study are as follows; 1) to measure technical efficiency of farmers in Lebanon and identify determinants affecting the inefficiency, especially among smallholders. This study analyzes fruit farms and vegetable farms separately due to difference of inputs; 2) to measure irrigation water efficiency and identify the factors affecting this efficiency, especially, the impact of participation to farmers' groups among smallholders in Lebanon; and 3) to draw policy recommendations based on the efficiency estimates.

This thesis consists of 6 chapters. Chapter 2 reviews the literature related to this study. This part reviews literatures mainly in four perspectives; productivity and efficiency analysis in agriculture and irrigation, cooperation among smallholders and technical efficiency, the technical efficiency of agriculture in the MENA region, and water resources, irrigation practice and irrigation water management in Lebanon. Chapter 3 presents the theoretical framework and empirical models for this study. The theoretical framework of this study consists mainly of a stochastic frontier production model, the technical inefficiency effect model, and irrigation water efficiency. Chapter 4 presents the survey strategy, study area and survey design of this study, in addition to summary of sample data. Chapter 5 shows the results of the analysis of the sample using the stochastic frontier production function, technical inefficiency and irrigation water efficiency analysis. Chapter 6 concludes and draws policy recommendation

CHAPTER 2

LITERATURE REVIEW

This research examines the impact of cooperation in water management among smallholders on technical efficiency and irrigation water efficiency. In this section, four issues in the literatures are reviewed; 1) productivity and efficiency analysis in agriculture and irrigation; 2) cooperation among smallholders and technical Efficiency; 3) the technical efficiency of the agriculture in the MENA region; and 4) water resources, irrigation practice and water management in Lebanon.

2.1. Productivity and Efficiency Analysis in Agriculture and Irrigation

A large of literature measured productivity and efficiency in agricultural both theoretically and empirically. Productivity and efficiency are sometimes used interchangeably; however, the strict definitions of these terms are different. Coelli *et al.* (2005) defined productivity as the ratio of outputs to the inputs in production. Productivity consists of total factor productivity and partial productivity; the former is productivity measure involving all factors of production and the latter is a productivity measure focusing on specific inputs. Coelli *et al.* (2005) warned that the partial productivity measure could provide a misleading indication when considered in isolation.

Farrell (1957) originally developed the concept of efficiency based on input oriented measures. A variety of efficiency measures have been developed from Farrell's formulation. In the definition of Farrell, efficiency consisted of two components; technical efficiency and allocative efficiency. Technical efficiency is defined as the ability of a firm to obtain maximum output from a given set of inputs while allocative efficiency is defined as the ability of a firm to use the inputs in optimal proportions, given their respective prices.

Bravo-Ureta and Pinheiro (1993) mentioned the importance of the distinction between the technical efficiency and technological change in the analysis of efficiency, whereby, technological change reflects a shift of the unit isoquant.

In efficiency analysis, Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are used in a number of empirical studies. Some literatures compare technical efficiency estimates between the two methods.

2.1.1. Data Envelopment Analysis and Stochastic Frontier Analysis

Data Envelopment Analysis (DEA) is a non-parametric approach for efficiency measurement by solving separate linear mathematical programming problems for each decision making unit (DMU). DEA constructs a non-parametric piece-wise frontier over the data. Efficiency measures are then calculated relative to this frontier. Charnes, Cooper and Rhodes (1978) proposed a model that had an input orientation and assumed constant returns to scale. Subsequent papers have considered alternative sets of assumptions, such as Faere, Grosskopf and Logan (1983) and Banker, Charnes and Cooper (1984), in which variable returns to scale models are proposed (Wadud and White 2000; Coelli et al. 2005; Theodoridis and Anwar 2011).

The stochastic frontier analysis (SFA) was proposed independently by Aigner, Lovell and Schmidt (1977) and Meeuesen and van den Broeck (1977). The advantage of stochastic frontier analysis is that measurement errors and other statistical noises are separated from technical inefficiencies. The stochastic frontier production function model incorporates a composite error structure with non-negative random error terms representing technical inefficiencies and the two-sided random error terms representing measurement errors and other statistical noise typical of empirical relationships. Under assumptions specific to the distribution of technical inefficiencies, the frontier is estimated by maximum likelihood methods (Bravo-Ureta and Pinheiro 1993).

Each of the DEA and SFA methods has its own advantages and drawbacks in analysis. The main advantage of DEA is that it neither requires a specific functional form for the frontier nor a particular distributional form for the technical inefficiency term (Coelli 1995; Coelli et al. 2005; Tang et al. 2014). DEA can analyze the efficiency of multiple outputs (Coelli 1995). On the other hand, the main drawback of DEA is that there is no consideration of the possible influence of measurement error and other statistic noises of estimated frontier due to the assumption that all deviations from the frontier are a result of technical inefficiency (Coelli 1995). Another drawback of DEA is that it is affected by outliers due to its deterministic characteristic (Bravo-Ureta et al. 2007, Tang et al. 2014).

The main advantages of the SFA is that it can accommodate statistical noise in the model and that its parametric specification of the technology can be tested statistically (Theodoridis and Anwar 2011). SFA is less sensitive to outliers (Tang et al. 2013). The major drawback of SFA is that it requires a pre-specification of the functional form and assumption of distribution of the technical inefficiency term (Coelli, 1995).

Wadud and White (2000) mentioned that the choice between DEA and SFA depended on the objective of the research, the type of firm and the available data. Coelli (1995) argued that DEA is attractive in efficiency analysis of multiple inputs and multiple output production. However, DEA is not preferable in the case where measurement errors or missing variables significantly affect the model since all deviations from the frontier in DEA are assumed to be the result of the technical inefficiency (Coelli 1995). The efficiency score estimated by the DEA approach is lower than that by SFA under this assumption (Theodoridis and Anwar 2011). Coelli (1995) mentioned that SFA is recommended for use in agricultural studies because the presence of measurement errors and the missing variables, such as weather conditions or natural disease, are common in agricultural data. In addition, SFA permits the conduction of statistical hypothesis testing regarding the production structure and the degree of inefficiency. Thus, this study adopted SFA for analysis of the technical efficiency of farmers in Lebanon.

2.1.2. Stochastic Frontier Production Function in Agriculture

A number of studies analyzed technical efficiency and its determinants in agriculture in developing countries. This section reviews the recent literature to the stochastic frontier analysis of agriculture in developing countries with respect to the choice of production function, variables of production function, choice of distribution of technical efficiency and determinants of inefficiency.

In empirical studies, the choice of the production function form is important since it clearly affects the inefficiency estimate (Ali and Byerlee 1991). Empirical studies targeting agriculture in developing countries adopted a Cobb-Douglas production function or translog production function specification for stochastic frontier analysis. Among the 24 empirical studies using SFA from 1984, the 17 studies used the Cobb-Douglas production function (Battese and Coelli 1995; Coelli and Battese 1996; Yao and Liu 1998; Ajibefun et al. 2002; Amaza and Olayemi 2002; Amos et al 2004; Binam et al. 2004; Amaza et al. 2006; Chinwuba and Odjuvwuederhie 2006; Amos 2007; Idiong 2007; Shehu and Mshelia 2007; Adeyemo and Akinola 2010; Tegegne et al. 2014; Haider et al. 2011; Bashir et al. 2012; Udoh 2016), The other 7 studies adopted the translog production function (Huang and Bagi 1984; Karagiannis et al. 2003; Ajibefun et al. 2006; Dhehibi et al. 2007; Ajewole and Folayan 2008; Tang et al. 2014; Yigezu et al. 2013; Chiona et al. 2014),

The Cobb-Douglas production function is a special form of the translog production function where the coefficients of the squared and interaction terms of input variables of the translog frontier are assumed to be zero. The main advantage of Cobb-Douglas is that it makes it easy to interpret the estimates because its coefficients directly represent the output elasticity of inputs (Tegegne et al. 2014). In addition, the Cobb-Douglas production function is free from degrees-of-freedom problem normally encountered in the translog production function (Amos 2007). The drawback of Cobb-Douglas production function is that returns to scale are restricted to take the same value across all firms in the sample, and elasticities of substitution are assumed to be equal to one (Coelli 1995).

The advantage of the tranlog production function is that it imposes no restrictions on returns to scale or substitution patterns (Coelli 1995). The drawback of the translog production function is that it is susceptible to multicollinearity and degrees of freedom problems (Coelli 1995; Amos 2007)

Despite its limitations, the Cobb-Douglas production function has been commonly chosen in farm efficiency analyses for both developing and developed countries. This is because it provides a computational advantage in obtaining estimates of technical and allocative efficiency due to its self-dual nature (Taylor et al. 1986; Bravo-Ureta and Evenson 1994; Bravo-Ureta and Pinheiro 1993). Kopp and Smith (1980) studied the impact of functional form on technical efficiency. It concluded that the impact on estimated efficiency was a discernible but rather small. Taylor et al. (1986) argued that the Cobb-Douglas production function was adequate as long as interest was in efficiency measurement and not an analysis of the general structure of the production technology. Thus, this research adopts Cobb-Douglas production function for analysis following Battese and Coelli (1995).

In terms of independent variables for the stochastic frontier production function explaining crop output, many empirical studies chose the following inputs: the amount of cultivated land, capital, seed, material inputs such as fertilizers, pesticides or other chemicals, man-day of labor inputs and the amount or frequency of irrigation water use.

Most empirical studies showed that the size of land is the most influential independent variable for increase of production than any other independent variable. Especially, studies focusing on smallholders showed this tendency (Adeyemo and Akinola 2010; Binam et al. 2004; Shehu and Mshelia 2007; Chiona et al. 2014; Ajewole and Folayan 2008; Gbigbi 2011; Haider et al. 2011; Yigezu et al. 2013; Bozoglu and Ceyhan 2007). Other studies showed that labor input is the most influential independent variable (Idiong 2007; Ajibefun et al. 2006; Ajibefun et al. 2002; Battese and Coelli 1995; Coelli and Battese, 1996; Karagiannis et al. 2003).

Basically, independent variables in the production function positively affect for increase of crop production; however, some studies showed the existence of independent variables negatively affecting production. In the study of Haider et al. (2011), land showed negative effects on production. This was attributed to the division and fragmentation of land, lack of proper irrigation and salinity problems. Shehu and Mshelia (2007) showed the amount of seed had negative influence on production due to over reliance by the farmers on old stock for planting as well as incorrect spacing. In the study of Udoh (2016), fertilizer had negative influence on production. This is why inorganic fertilizer is used mostly as complementary land-augmenting inputs to organic manure. These reasons depend on context and environment, so analysis requires adequate knowledge of the environment of the agricultural production.

2.1.3. Technical Inefficiency Effect Modeling in Agriculture

The Stochastic Frontier Analysis requires the specification of the distribution of error terms associated with technical inefficiency. The distribution of technical inefficiency is assumed to be one of following; half-normal, exponential (Aiger, Lovell and Schmidt 1977), truncated normal (Stevenson 1980) and gamma (Greene 1990), while error terms associated with statistical noises are assumed to have independently and identically normal random distribution with mean of zero and distribution of σ_v^2.

Among empirical studies of technical efficiency in agriculture, most adopt the half normal distribution or truncated normal distribution. The half normal distribution is assumed to be non- negative and independently and identically normally distributed with zero mean and a variance of σ_u^2, i.e. $u_i \sim N^+(0, \sigma_u^2)$. Truncated normal distribution is assumed to be non-negative and independently and identically normally distributed with mean of μ and a variance of σ_u^2, i.e. $u_i \sim N^+(\mu, \sigma_u^2)$. μ is freely estimated and sometimes expressed as $\mu = z_i\sigma$, where z is a $(1 \times \mathrm{m})$ vector of observable farm specific variables hypothesized to be associated with technical inefficiency, and σ is an $(\mathrm{m} \times 1)$ vector of unknown parameters to be estimated.

The most of the recent empirical research adopted a truncated normal distribution rather than half-normal distribution for error terms associated with technical inefficiency (Battese and Coelli 1995; Coelli and Battese 1996; Yao and Liu 1998; Ajibefun et al. 2002; Karagiannis et al. 2003; Binam et al. 2004; Croppenstedt 2005; Ajibefun et al. 2006; Chinwuba and Odjuvwuederhie 2006; Bozoglu and Ceyhan 2007; Idiong 2007; Amor and Muller 2010; Haider et al. 2011; Yigezu et al. 2013; Chiona et al.

2014).

Coelli et al. (2005) mentioned that some researchers avoid half-normal distributions due to their mode at zero. This implies that most inefficiency effects were in the neighborhood of zero and the associated measures of technical efficiency would be in the neighborhood of one. The truncated normal and gamma distribution may have a wide distribution, which can have non-zero modes. Coelli et al. (2005) also argued it might be difficult to separate technical inefficiency from other statistical noise when their probability density functions had similar shapes. Thus, this research assumes that the technical inefficiency term to be truncated normal.

In the estimation of technical inefficiency determinants in the stochastic frontier production function, several studies in the literature used the two-step procedure. In the first step, technical inefficiency is estimated from the production function ignoring the fact that the technical inefficiency is a function of some other variables. Once the technical inefficiency is estimated, it is further regressed in the second stage on a set of variables that are supposed to explain differences in technical inefficiency among farms (Kumbhakar et al. 1991).

Kumbhakar et al. (1991), Battese and Coelli (1995)and Coelli (1995) argued that a separate second-stage analysis is inconsistent, pointing out problems with this two-stage procedure. First, the efficiency effects are assumed to be independently and identically distributed, however, in the second stage, they are assumed to be a function of a number of firm-specific factors which implies that they are not identically distributed. Second, technical inefficiency can be correlated with the inputs, which causes inconsistent estimates of the parameters as well as technical inefficiency. Third, the standard ordinary least squares estimates in the second step may not be appropriate since technical inefficiency is one-sided. Furthermore, the estimated value of technical inefficiency should be non-positive for all observations. Kumbhakar et al. (1991) argued that using a one-step procedure for the estimation could overcome these problems. Thus, this research adopts the single-stage Maximum Likelihood procedure for estimation of technical inefficiency effects, following Battese and Coelli (1995)

In empirical studies of agriculture, the means of output-oriented technical efficiency of agriculture range from 34.87 percent (Udoh 2016) to 95.70 percent (Shehu and Mshelia 2007) and most of them locates in the region of 80 percent. Since the conditions are different from region to region, it is almost meaningless to compare the technical efficiency.

As determinants of inefficiency, many empirical studies adopted the following factors: age of farmer, farming experience, education of farmer, extension visits, availability of credit, membership of cooperatives, farm size and off-farm income. Factors related to increase of human capital such as age of farmer, farming experience, education of farmer and extension visits showed a decrease of technical inefficiency in many studies (Coelli and Battese, 1996; Amos et al 2004; Ajibefun et al. 2006; Amaza et al. 2006; Bozoglu and Ceyhan 2007; Dhehibi et al. 2007; Ajewole and Folayan 2008; Adeyemo and Akinola 2010; Gbigbi 2011; Yigezu et al. 2013; Chiona et al. 2014; Tegegne et al. 2014; Udoh 2016). However, some studies showed the opposite effect. The age of farmers and education had significantly positive effect on technical inefficiency in Tegegne et al. (2014) and farm experience in Chinwuba and Odjuvwuederhie (2006), which implied that older and educated people are more inefficient in production. Both studies mentioned this reason that younger farmers were more prompt to adopt new technology than their older counterparts.

Availability of credit showed a negative effect on technical inefficiency in many studies (Binam et al. 2004; Amaza et al. 2006; Chinwuba and Odjuvwuederhie

2006; Bozoglu and Ceyhan 2007; Ajewole and Folayan 2008; Gbigbi 2011; Bashir et al. 2012; Chiona et al. 2014) and off-farm income also showed negative effect on it (Bashir et al. 2012; Chiona et al. 2014; Tegegne et al. 2014). Credit enables farmers to hire more labors, purchase adequate amounts of agricultural inputs and invest in new technology to enhance productivity. In contrast, Ajewole and Folayan (2008) showed that off-farm income had a positive effect on the technical inefficiency. The reason is that less time was allocated to vegetable farm work due to the increase of off-farm work, which decreased technical efficiency.

Farm size showed negative effects on technical inefficiency in many studies (Ajibefun et al. 2006; Coelli and Battese, 1996; Dhehibi et al. 2007). A membership to farmers' cooperatives had a negative effect on technical inefficiency due to its assisting farmers in obtaining inputs or marketing (Adeyemo and Akinola 2010) and sharing information on farming practice (Binam et al. 2004; Idiong 2007) while Gbigbi (2011) showed the opposite effect, mentioning that this could be attributed to inadequate efforts by the existing farmers' cooperatives in influencing technology uptake.

2.1.4. Irrigation Water Efficiency

McGuckin et al. (1992) defined irrigation water efficiency as the ratio of effective water use to the water applied to the crop. Irrigation water efficiency in this definition is a physical measure of a given irrigation technology. Based on this definition, change of the irrigation method can increase its efficiency; for example, change from furrow irrigation to sprinkler irrigation or change from sprinkler irrigation to drip irrigation can be estimated effective at the expense of an increase of capital. In this definition, technical inefficiency among the same irrigation method cannot be estimated.

Farrel (1957) mentioned that technical efficiency would reflect a measure of management capability. In Farrel's definition, using the same irrigation method, technical inefficiency can be estimated differently due to inappropriate irrigation management. The definition of McGuckin et al. (1992) cannot compare irrigation practice of different level of management.

Karagiannis et al. (2003) proposed alternative measurement of irrigation water efficiency by developing an equation which Reinhard et al. (1999) obtained from the translog stochastic production function to measure environmental efficiency. This equation is a non-radial, input-oriented efficiency measure of input-specific technical efficiency (Kopp 1981), which is defined as the ratio of the minimum feasible water use to observed water use conditional on production technology and observed levels of output and other inputs used.

Karagiannis et al. (2003) examined the irrigation efficiency in Greece, Dhehibi et al. (2007) that in Tunisia and Yigezu et al. (2013) that in Syria by using the two-stage estimation procedure to obtain the irrigation efficiency. Battese and Coelli (1995) noted that a separate two-stage analysis was inconsistent because of the assumption that the technical inefficiency effects in the stochastic frontier were independently, identically distributed. However, the irrigation efficiency is calculated from the parameter estimates and the estimated one-sided error component of the stochastic production frontier, and it is not directly related to distributional assumptions (Karagiannis et al. 2003).

The mean irrigation efficiency is 47.20 percent in Greece, 53.00 percent in Tunisia and 69.90 percent in Syria, which are lower than the mean technical efficiency, 70.17 percent, 67.73 percent and 78.20 percent, respectively.

In the empirical result of Karagiannis et al. (2003), the introduction of technological innovation, use of modern greenhouse technology, extension visits, and education affected positively both technical and irrigation water efficiency while high share of leased land affects negatively both efficiencies. Use of private well and chemical use per unit of land affect negatively irrigation efficiency but do not affect technical efficiency. Participation in local co-operative, bank loan gross returns per unit of land, and farm size did not affect both efficiencies. Farmer's age and off-income affect technical efficiency but not irrigation water efficiency.

The use of sprinklers for irrigation and farm experience positively affected the technical efficiency while the size of wheat cultivating area, use of artesian wells and family size negatively affected the technical efficiency. Among them, irrigation method affected water efficiency the most (Yigezu et al. 2013).

Farm size positively affected technical efficiency but did not affect the irrigation water efficiency. The farmers' age, education level, agricultural training, the share of productive trees, the perception of the availability of water and the share of family labor did not affect both technical efficiency and irrigation water efficiency (Dhehibi et al. 2007).

In the empirical studies above, the introduction of technological innovation, modern greenhouse technology, extension visits, and education affected positively irrigation water efficiency while a high share of leased land, use of private well and chemical use per unit of land affect negatively irrigation efficiency Karagiannis et al. (2003). However, education level, agricultural training did not affect the efficiency in Dhehibi et al. (2007). The farmer's age and farm size did not affect irrigation efficiency in both Karagiannis et al. (2003) and Dhehibi et al. (2007).

2.2. Cooperation among Smallholders and the Technical Efficiency

There has been a debate about the relationship between farm size and productivity in developing countries. This section focuses on the technical inefficiency of smallholders, and the relationship between cooperation in irrigation and technical efficiency.

2.2.1. Smallholders and Technical Inefficiency Effect

Relationship between farm size and productivity has been controversial after Shultz (1964) indicated smallholders in traditional farmers were reasonably efficient. A number of empirical studies have provided evidence that crop productivity per unit of land declined with an increase in farm size, supporting the inverse relationship between productivity and farm size in developing countries (Sen 1962; Berry 1972; Lau and Yotopoulos 1973; Trosper 1978). This is under the assumption that smallholders in a traditional agriculture rely on their own resources and that they have adjusted use of the resources to the most efficient combination in their conditions (Ali and Byerlee; 1991).

However, recent empirical studies showed the opposite conclusion (Carter 1984; Bravo-Ureta and Rieger 1990; Kumbhakar 1993). It is argued that smallholders could not adjust allocative decision to maintain an efficient allocation of resources due to a continually changing technical and economic environment after Green Revolution (Carter 1984; Ali and Byerlee 1991). Thus, raising of productivity among smallholders has become a primary concern.

A number of empirical studies examined technical efficiency and factors of inefficiency among small-scale farmers in developing countries by using the stochastic frontier production function. Many of empirical studies showed that the technical inefficiency was reduced by availability of credit (Binam et al. 2004; Chinwuba and Odjuvwuederhie 2006; Chiona et al. 2014; Ajewole and Folayan 2008; Gbigbi 2011), off-farm income (Tegegne et al. 2014; Chiona et al. 2014; Ajewole and Folayan 2008), in addition to increase of education (Adeyemo and Akinola 2010; Binam et al. 2004; Shehu and Mshelia 2007; Chinwuba and Odjuvwuederhie 2006; Ajibefun et al. 2006; Gbigbi 2011), farming experience (Adeyemo and Akinola 2010; Tegegne et al. 2014; Ajibefun et al. 2006; Amos et al 2004; Gbigbi 2011) and use of extension service (Tegegne et al. 2014; Ajewole and Folayan 2008; Gbigbi 2011). These studies support the fact that the technically dynamic agriculture after Green Revolution depends much more on knowledge of farm management and purchase of the adequate amount of material inputs and capitals (Ali and Byerlee 1991).

Moreover, the membership to farmers' cooperative showed a positive effect on the reduction of technical inefficiency (Adeyemo and Akinola 2010; Binam et al. 2004; Idiong 2007). This membership assisted farmers in obtaining material inputs or marketing and sharing information on farming practice, which contributed to increasing technical efficiency.

The smallholders without enough financial resources are being faced with the difficulties in increase crop productivity after the Green Revolution; however, they might overcome such difficulties by cooperation with other farmers.

2.2.2. Cooperation in Agriculture and Technical Efficiency

Cooperation in agriculture among famers can proceed in informal farmers' group, cooperative or water user association. Empirical studies analyzed the effect of these kinds of farmers' cooperation on technical efficiency of farmers.

Abate et al. (2014) studied the effects of agricultural cooperatives on smallholders in Ethiopia. They showed that membership to an agricultural cooperative significantly reduced technical inefficiency of members by about 5 percent. The mean technical efficiency of cooperative members was also higher than that of non-members by 9 percent points. Abate et al. (2014) mentioned that agricultural cooperatives enabled smallholders to access productive technology and embedded support services such as training.

Sharma et al. (2001) compared the technical efficiencies of the government-managed and farmer-managed irrigation systems among farmers in Nepal. In this study, irrigation management showed a significant influence on production. The farmers from the farmer-managed system were found to be more efficient than those from the government system, showing higher mean technical efficiency (83.7% with the farmer-managed irrigation systems and 73.8% with the government-managed irrigation systems).

Tang et al. (2014) studied the effect of management reform in 1998 in China on irrigation water efficiency among private companies, joint-stock co-operatives or water user association. Irrigation water efficiency of water user association members was higher than that of joint-stock co-operative members and private companies. Under water user associations, farmers could be more involved in water management, which contributed to an increase in technical efficiency.

Cooperation in agriculture supports farmers to have access to new production technology and farm management knowledge and also enhance involvement of resource management, which can contribute to increase of the technical efficiency among smallholders.

2.3. The Technical Efficiency of the Agriculture in The MENA Region

There are not many studies regarding the technical efficiency of agriculture in the Middle East and North Africa region. Belloumi and Matoussi (2006) and Amor and Muller (2010) studied the technical efficiency and inefficiency effects of date farms, and cereal, fruits tree and vegetable farms in Tunisia while Croppenstedt (2005) studied wheat farms in Egypt, and Bozoglu and Ceyhan (2007) vegetable farms in Turkey. In addition to technical efficiency and inefficiency effects, Dhehibi et al. (2007) and Yigezu et al. (2013) studied the irrigation efficiency of citrus farms in Tunisia and wheat farms in Syria respectively, following the method of Reinhard et al. (1999), the same as Karagiannis et al. (2003).

Mean technical efficiency is lowest in vegetable farms in Tunisia (54percent) and highest in vegetable farms in Turkey (82percent). Other mean technical efficiencies ranged from 68percent to 81percent.

In stochastic frontier production function studies, significantly positive variables for yields were labor (man-day) (Amor and Muller 2010; Belloumi and Matoussi 2006; Yigezu et al. 2013; Bozoglu and Ceyhan 2007), irrigation water (m^3) (Amor and Muller 2010; Belloumi and Matoussi 2006; Yigezu et al. 2013), farm size (acre, hectare or feddan) (Dhehibi et al. 2007; Croppenstedt 2005; Bozoglu and Ceyhan 2007)

In the technical inefficiency model, farmers' experience had a significantly negative effect (Yigezu et al. 2013; Bozoglu and Ceyhan 2007). Age of farmers had a negative impact in all cases in Tunisia but significant only in Dhehibi et al. (2007) while it had positive impact in Syria and Turkey. Education had significantly negative impact in Bozoglu and Ceyhan (2007) while it had positive effect but not significantly (Amor and Muller 2010; Belloumi and Matoussi 2006; Yigezu et al. 2013). Fertilizer has significantly negative in Croppenstedt (2005). Belloumi and Matoussi (2006) studied the effect of WUA on technical inefficiency in date farms in Tunisia by using dummy variable. Not joining WUA had positive impact on the technical inefficiency but the effect was insignificant.

The mean irrigation efficiency score is 69.9percent in Syria and 53percent in Tunisia, both of which were lower than scores of the technical efficiency, 78.2percent and 67.7percent respectively. The farmers' age gave significantly positive impact on irrigation efficiency in Tunisia.

2.4. Water Resources and Irrigation Water Management in Lebanon

In Lebanon, the total annual available water resources from a number of sources are estimated at about 8.6 billion cubic meters, of which about 4.0 billion cubic meters per year are lost to surface evaporation. Of the remaining water, about 700 million cubic meters per year flow to neighboring countries, 150 million cubic meters infiltrates to groundwater beyond the southern boundaries and 700 million cubic meters are lost to the sea by deep percolation. This leaves about 3.0 billion cubic meters remaining in Lebanon, of which 2.1 billion cubic meters is readily available for utilization (World Bank 2003).

The net exploitable water potential was estimated to be 2.1 billion cubic meters in 2011. Almost 60 percent of the available water resources are used for the agricultural sector. More than half of the agricultural land of Lebanon is under irrigation (Ministry of Agriculture 2014).

The assessment of FAO (2015) indicates that 36 per cent of the Lebanese farmers rely on traditional irrigation while 16 per cent solely rely on direct precipitation. The majority of irrigation techniques in Lebanon are surface irrigation, which is used by 57.2% of all irrigated lands (Ministry of Environment of Lebanon and UNDP 2011). Among farms irrigated by surface water, about 86 percent of them were irrigated by surface irrigation, 9 percent by sprinkler irrigation, and 5 percent by drip irrigation while among farms irrigated by ground water, about 43 percent of them are irrigated by surface irrigation, about 45 percent by sprinkler and 12 percent by drip irrigation. About half of small and medium irrigation schemes suffer from lack of proper maintenance. However, small schemes which are operated by Local Water Committees or farmers' group are generally well maintained, especially when farmers are involved (World Bank 2003).

According to FAO (2015), 39 percent of farmers use wells and 31 percent of them use canals as water sources. SPNL and MADA (2013) suggested that the use of drip irrigation and water collection pools will help resolve the water availability problems as a mean of promoting sustainable technologies.

Several governmental and autonomous agencies are involved in irrigation water management in Lebanon. Ministry of Energy and Water (MOEW) assumes jurisdiction over the water resources in Lebanon. MOEW conserves and controls the water resources, both surface and underground water by exercising administrative supervision over the Water Associations (WA) and the Litani River Authority (LRA). MOEW studies situations of the water resources of Lebanon in global perspective to prepare the national water master plan and design, implement and operate large hydraulic facilities (World Bank 2003).

Under MOEW tutelage, the Litani River Authority (LRA) and the four Water Authorities (WA), which had consisted of the 22 Regional Water Authorities (RWA) before 2002, operate water management with various degrees of autonomy. In addition, under the tutelage of the RWAs, there were 209 local water committees, which were formed between 1984 and 1990 (Comair 2007).

The Litani River Authority (LRA) was established in 1954 to develop the Litani River Basin irrigation and hydropower water schemes and build electrical power stations and distribution networks in all Lebanese territory. The four Water Authorities

(WAs) were organized from all Regional Water Authorities (RWAs) in 2002 to take over the management of the irrigation, potable water and sewerage schemes based on law (No. 221). However, due to the technical, administrative and financial constraints, they are physically not able to undertake these tasks bestowed upon them by the law (World Bank 2003).

The Local Water Committees (LCs) and farmers' groups were mainly established after the civil unrests of the 1980s. In general, the role of these committees is restricted to the operation, maintenance, rehabilitation and renovation of the networks and equipment. This keeps the responsibility for studying water requirements, development of water resources and design and execution of extension of existing networks with the MOEW. The LCs and farmers' groups are most involved with the operation and maintenance of the small and medium irrigation schemes. The MOEW used to pay appointed LCs some subsidies to partially cover any shortfall in operation and maintenance costs, and also to rehabilitate those schemes. However, in 2003, the MOEW stopped paying subsidies to LCs, which are now obliged to collect fees from farmers for maintenance and water guards (World Bank 2003).

Among water authorities, the most successful projects are done by the LCs and farmers' group which stakeholders are involved in management of operation and maintenance. It is now more urgent to enhance involvement of stakeholders in irrigation through establishment of Water Users' Association in place of the present LCs and farmers' group since GOL stopped subsidizing O&M of irrigation schemes operated by local water committees (World Bank 2003). However, this requires a legal framework to govern WUA and the amendments of Laws 221, 24 and 337. Also, no efforts have been made to prepare a technical and administrative staff for wastewater treatment in plant management and water reuse (Comair 2007).

CHAPTER 3

THEORETICAL FRAMEWORK AND EMPIRICAL MODEL OF THIS STUDY

This Chapter reviews theoretical framework and empirical model of this study.

3.1. Theoretical Framework

3.1.1. The Stochastic Frontier Production Function

The stochastic frontier production function is proposed independently by Aigner, Lovell and Schmidt (1977) and Meeuesen and van den Broeck (1977). The advantage of stochastic frontier analysis is that measurement errors and other statistic noise are separated from technical inefficiencies. Following Battese and Coelli (1995), the stochastic frontier production function is specified as,

$$y_i = f(x_i, w_i; \beta) exp(v_i - u_i)$$

where, for the i^{th} farm, y denotes the quantity of output produced; x is a $(1 \times \mathrm{k})$ vector of non-irrigation water quantities of inputs; w is the quantity of irrigation water; β is a $[1 \times (\mathrm{k}+1)]$ vector of unknown parameters to be estimated; v is a random error representing statistical noise, which is independently and identically normally distributed with zero mean and variance σ^2; u is a non-negative random variables associated with technical inefficiency, which is assumed to be a truncated normal distribution. u is obtained by truncation at zero of the normal distribution with mean, $z\sigma$ and variance σ^2. z is a $(1 \times \mathrm{m})$ vector of explanatory variables associated with the technical inefficiency of production of the firm. Finally, σ is $(1 \times \mathrm{m})$ vector of unknown coefficients to be estimated.

The Stochastic frontier analysis requires the specification of assumptions regarding the distribution of the error terms associated with the technical inefficiency, while error terms associated with statistical noises are assumed to have independently and identically normal random distribution with mean of zero and distribution of σ_v^2. Aigner, Lovell and Schmidt (1977) and Meeuesen and van den Broeck (1977) assumed it to be half-normal distribution, which is obtained by truncation at zero of the normal distribution with zero mean and variance σ^2. The half-normal distribution is under the assumptions that the mode of u is expected to occur at zero and the likelihood of inefficient behavior monotonically decreases as levels of inefficiency increase.

Stevenson (1980) proposed the truncated normal distribution for assumption in place of half-normal distribution. The truncated normal distribution assumes u to be distributed as a truncated normal with mode μ defined by $\mu_i = \sigma_0 + \sum_{j=1}^{J} \sigma_{ji} z_j$. It was not clear why the mode of u was assumed to be at zero. In addition, factors related to managerial efficiency, such as degree of educational training, were not likely distributed with such a monotonically declining density function over the population. The possibilities of a non-zero mode for the density function of u were likely to be more tenable. Moreover, the truncated normal may have a wide range of distributional shapes, which can have non-zero modes. If the probability density functions of u_i and v_i have similar shapes, it might be difficult to separate technical inefficiency effect from other statistical noise (Coelli et al. 2005).

However, some studies compared distributions of technical inefficiency terms and concluded that the assumption of the distribution resulted in significant differences in technical efficiency. Thus, this study adopts half normal distribution as the assumption of distribution of error terms associated with technical inefficiency.

3.1.2. The Technical Inefficiency Effect Model

The technical inefficiency effect, u_i, in the stochastic frontier model is specified as,

$$u_i = z_i\delta + W_i$$

where W_i is an independently and identically distributed random variable with zero mean and variance, σ^2, defined by the truncation of the normal distribution such that $W_i \geq -z_{it}\sigma$ (Battese and Coelli 1995).

The parameters of the stochastic frontier and the model for the technical efficiency are estimated by the method of maximum likelihood. The likelihood function is expressed in terms of the variance parameters, $\sigma_s^2 \equiv \sigma_v^2 + \sigma^2$ and $\gamma \equiv \sigma^2/\sigma_s^2$. γ lies between 0 and 1. This represents the level of inefficiency and $\gamma = 0$ implies no technical efficiency.

Regarding technical efficiency, Reinhard et al. (1999) defines it as,

$$TE_i = [max\{\phi : \phi y_i \leq F(x, w_i)\}]^{-1} = \frac{|observed\ output|}{|maximu\ feasible\ output|}$$

Following Battese and Coelli (1995), the technical efficiency from stochastic frontier production function for the i^{th} firm is defined as,

$$TE_i = \frac{E(y_i|u_i, x_i)}{E(y_i|u_i = 0, x_i)} = \exp(-u_i) = \exp(-z_i\delta - W_i)$$

Since $u_i \geq 0$, $0 \leq \exp(-u_i) \leq 1$. The computer program calculates predictions of individual firm technical efficiency from estimated stochastic production frontiers.

3.1.3. The Irrigation Water Efficiency

The technical efficiency above is an output-oriented and multi-factor measure.

It is incapable of identifying the efficiency of individual inputs since such a measure encompasses the efficiency of total factor employment and treats the contribution of each input to productive efficiency equally to be measured radially. In order to measure irrigation water efficiency, an input-oriented and single-factor measure of technical efficiency measure should be considered, which is based on the non-radial notion of input-efficiency (Kopp 1981). Following Reinhard et al. (1999) and Karagiannis et al. (2003), irrigation water efficiency (IE), an input-oriented and single-factor technical efficiency, is defined as,

$$IE_i = min\{\theta : F(x_i, \theta w_i) \geq y_i\} = \frac{|the\ minimum\ fesisble\ irrigation\ water\ use|}{|the\ observed\ irrigation\ water\ use|}$$

3.2. Empirical Model

This study estimates the production frontier for the following Cobb-Douglas function;

$$lny_i = \beta_0 + \sum_{j=1}^{J} \beta_j lnx_{ji} + \sum_{j=1}^{J} \beta_j lnx_{ji}(dummy) + \beta_w lnw_i + v_i - u_i$$

where y_i is output production (kg), x_1 is land (m^2), x_2 is fertilizer (kg), x_3 is pesticide (kg), x_4 is labor (number of persons employed), x_5 is seeds (g) for vegetables and x_6 is area of greenhouse (m^2) for vegetables. $x_2(dummy)$ is 1 if the amount of fertilizer is missing, otherwise 0. $x_3(dummy)$ is 1 if the amount of pesticide is missing, otherwise 0. $x_4(dummy)$ is 1 if the number of labor is missing, otherwise 0, $x_5(dummy)$ is 1 if the amount of seed for vegetables is missing, otherwise 0 and $x_6(dummy)$ is 1 if the farm is located in Bcherre or Mchaytiyyeh, otherwise 0. $w_i$is water (m^3). $x_6(dummy)$ is based on a quantity of precipitation per year. β is one estimated parameter, and v_i is one error term representing statistical noise, which is assumed to be independently and identically normally distributed with zero mean and variance σ^2, i.e. $v_i \sim iidN(0, \sigma_v^2)$, and u_i is a non-negative random variables associated with technical inefficiency, which is assumed to be independently and identically normally distributed with mean, $z\sigma$ and variance σ^2, i.e. $u_i \sim iidN^+(0, \sigma_u^2)$.

This study adopts dummy variables for zero-value inputs of fertilizer, pesticides, labor and seeds for vegetables. Battese (1997) argued that the use of dummy variables for zero-value inputs was required to estimate unbiased parameters.

The parameters are obtained by the method of maximum likelihood using Stata ver11.

The technical inefficient effect, u_i, is estimated as follows,

$$u_i = z_i\delta + W_i$$

where δ is a (6×1) vector of unknown coefficients to be estimated and z_1 is age of farmer (years), z_2 is schooling of farmer (years), z_3 is adoption of furrow irrigation as a method of irrigation (dummy), z_4 is the participation of farmers group of irrigation water or WUA (dummy), z_5 is participation in maintenance of irrigation infrastructure (dummy) and z_6 is total irrigated farm area, W_i the truncation of the normal distribution with zero mean and variance, σ^2, such that the point of truncation is $-z_{it}\sigma$

Technical inefficiency is estimated as following,

$$TE_i = \exp(-u_i) = \exp(-z_i\delta - W_i)$$

Farm-specific estimates of the irrigation water efficiency are derived by using fully efficient stochastic frontier production function and the following relations developed by Reinhard et al. (1999). However, this study adopted a Cobb-Douglas production function though Reinhard et al. (1999) used translog production function.

The logarithm form of the stochastic frontier production function is specified as,

$$lny_i = \beta_0 + \sum_{j=1}^{J} \beta_j lnx_{ji} + \beta_w lnw_i + v_i - u_i$$

The logarithm of the output of fully irrigation water efficient producer is defined by replacing w_i with w_i^F and setting $u_i = 0$.

$$lny_i = \beta_0 + \sum_{j=1}^{J} \beta_j lnx_{ji} + \beta_w lnw_i^F + v_i$$

The logarithm of irrigation water efficiency is defined as $lnIE_i = lnw_i^F - lnw_i$ and obtained by subtracting the two equations above,

$$\beta_w(lnw_i^F - lnw_i) + u_i = 0$$

which can be solved for $lnIE_i = lnw_i^F - lnw_i$ to obtain

$$\ln IE_i = -u_i/\beta_w$$

this can be rewritten

$$IE_i = exp(-u_i/\beta_w)$$

Battese and Coelli (1995) noted that a separate two-stage analysis was inconsistent because of the assumption that the technical inefficiency effects in the stochastic frontier were independently, identically distributed. However, the irrigation efficiency is calculated from the parameter estimates and the estimated one-sided error component of the stochastic production frontier, and it is not directly related to distributional assumptions (Karagiannis et al. 2003). Thus, irrigation efficiency is estimated by two-stage procedure. Explaining efficiency differential is defined as

$$\ln IE_i = h(z_i, \delta) + e_i$$

where $h(z_i, \delta)$ is the deterministic core of the regression model, δ is the vector of the parameters to be estimated and e_i is an independently and identically normally distributed random variables with zero mean and constant variance. This is estimated with the standard Ordinary Least Square method.

CHAPTER 4

STUDY AREAS AND DATA

This section presents the survey strategy of this research, study areas, survey design and a summary of sample data with respect to farm and crops.

4.1 Survey Strategy

Data for this study were collected in the study areas from May 2016 to July 2016, based on a farmer's household survey. The strategy of data collection was snowballing. I visited all farmers and asked them to introduce other farmers in the region. I conducted face-to-face interviews, following a prepared survey questionnaire after informed consent. The survey questionnaire and informed script were prepared both in English and Arabic. They were reviewed and approved by Institution Review Board of American University of Beirut.

4.2. Study Areas

Areas selected for this study are Mchaytiyyeh, Bcherre, Anjar and the Bekaa Valley. I categorized these areas into three; 1) area with farmers' group for irrigation water management or Water Users' Association (WUA) where farmers participate in O&M in irrigation infrastructure, namely Mchatiyyeh; 2) areas with farmers' group or WUA where farmers do not participate in O&M in irrigation infrastructure, namely Anjar and Bcherre; 3) and areas without any WUA and farmers group for O&M in irrigation infrastructure, namely Baalbek and Majdallon.

4.2.1 Mchaytiyyeh

The village of Mchaytiyyeh is situated at an altitude of 1406m in the northern

Beqaa valley. The Water Users' Association (WUA), Agricultural Cooperative Association of Mchaytiyyeh, was created in 1997 by the initiative of Dr. Hanna Khoury. The WUA constructed a 150-meter-deep well, an artificial pond and closed irrigation canal network made of 8-inch pipes in 1997, funded by a donation from USAID, EU and the embassy of Japan in Lebanon. The well and reservoir are located 7 to 8 km uphill from the village. The three reservoirs have already been constructed since the first reservoir was constructed. Water also comes from melted snow, in addition to, water extracted from the well. The small valley of Mchaytiyyeh is karstic and water is scarce there. Before establishment of the WUA, the farmers used to grow only rain fedcrops; mainly cereals. However, after the establishment of the WUA, farmers reclaimed more lands and grew apples due to sustainable water supply (Gharios 2009; Tegoni et al. 2016).

The WUA has legal status in Lebanon and it is now overseen by the directorate of Agricultural Cooperatives at the MoA (Gharios 2009). The WUA possesses one big tractor, two small tractors and mechanical sprayers. The WUA provides farmers with services such as renting tractors or spraying of pesticide by sharing the cost among them. In 2016, approximately 60 farmers are members in the association. All farmers have to adopt drip irrigation to reduce water waste in place of surface irrigation. When farmers need water, they contact a caretaker and he arranges distribution. Each farmer can irrigate 100-liter water per tree each time. Flow meters are attached to the pipes in each farm to measure water consumption. The caretaker opens the valves of secondary pipes in each farms and close them after checking the amount of water flow.

Each farmer pays one dollar per tree annually. In addition, all farmers are also engaged in working for the maintenance of the irrigation network and artificial pond. Each of them work 4 days for maintenance of main pipe and 5 days for maintenance of the artificial ponds in a year.

4.2.2. Anjar

Anjar is an Armenian town located at the altitude of 850 m in the eastern part of the Bekaa valley. In Anjar, farm area and residence area is flatly divided. Farm area consists of two sizes of plots; 7000 m^2 plots and 4000 m^2 plots. The former is land with fruits trees mainly irrigated by the Local Water User Association of Anjar (ALWUA) using a canal system and the latter is arid land for vegetables irrigated by pressurized and surface irrigation. On the establishment of irrigation network in Anjar, 7000 m^2 farm plots and 4000 m^2 farm plots were distributed to each household.

The canal system in Anjar is a network of gravity-open canal from the spring of Anjar and continues downward towards the agricultural fields. Between 1940 and 1944, in the era of French Mandate, the current canal water system and ALWUA were established to manage and distribute irrigation water among farmers. The ALWUA employs 12 caretakers, who are in charge of the maintenance of the canals and roads in the farm region and 4 to 5 guards on the field to prevent thefts. The ALWUA has a main office in the village and three water offices in the field to manage the farmers' daily issues.

When farmers need water, they tell the main office when they need water. Then, one of caretakers opens sluice of the irrigation network of each farm for ordered duration of time. Fruits farmers pay 50 USD per plot for every use of irrigation water in spite of the duration of use while vegetable farmers pay 500 USD per plot for 4 months of use of irrigation water from the canals.

4.2.3. Bcherre

The town of Bcherre is locates at an altitude of about 1,500 m in the Kadisha Valley in northern Lebanon. Farms are distributed at the higher altitudes of the town. Most farmers belong to farmers' groups of irrigation operation and maintenance. The water comes from the spring of the Saint Simon through the closed irrigation canal made of 8-inch pipes. The primary canals run along each farm. Open gravity-flow irrigation network made of rocks and blocks was established in a few centuries ago. However, with the initiative of the Minister of Agriculture after 2000, closed gravity-flow irrigation network was replaced by putting the 8-inche pipes on the canal and covering them by concrete.

A farmers' group was also established by accompany of establishment of irrigation canals from the spring Saint Simon. The farmers' group is an informal entity without legal status. Most farmers in Bcherre belong to the group which is engaged in the operation of irrigation water distribution and maintenance of the infrastructure. The group employs caretakers of the irrigation infrastructure. When the farmers use irrigation water from the canal, they call to the caretakers to inform when they need it. The caretakers come to each farm and open the valve of the canal. After appointed hours, the caretakers come back and close the valve. Caretakers calculates the bill of irrigation water use annually and each farmer pays irrigation water once a year. As a rule, fruits farmers can use the irrigation water once in a month while vegetable farmers can use irrigation water once in 15 days.

4.2.4. Bekaa valley around Baalbek and Majedallon

Baalbek and Majedallon are located in the central Bekaa in the Anti-Lebanon foothills east of the Litani River. The Bekaa valley is a high-altitude fertile plain at an average altitude of 900 m with a semi-continental climate. Typical annual average rainfall ranges between 200-600. With a diversity of agricultural systems (rainfed and irrigated), the Bekaa hosts the largest proportion of the cereal, vegetable and fruit farms in Lebanon. The area produces 70% of all roughage consumed by livestock in the country and accounts for 40% of its rangelands (Hamadeh et al. 1996; World Bank, 2003).

While surface irrigation is still predominant in North Lebanon and Akkar, drip and sprinkler irrigation are widespread in the Bekaa and Baalbek (FAO 2014). Drip and sprinkler irrigation systems are used on a wide range of crops (Ministry of Agriculture 2003). In this region, irrigation water supplies are mainly from groundwater sources that are being depleted (Ministry of Agriculture 2003). Each farmer develops his own well for irrigation without forming farmers group for irrigation water management.

4.3 Survey Design

A survey was designed to measure the technical efficiency and irrigation water efficiency among farmers in Lebanon, mainly consisting of three parts; 1) general questions; 2) farm and agriculture related questions and; 3) irrigation infrastructure and water use questions.

The general questions are socio-economic questions about farmers, such as the age of farmer, gender and highest education of household head, aiming to examine factors affecting technical inefficiency and water use efficiency.

. The farm and agriculture related questions collect data on the outputs and inputs of crop production in order to measure the efficiencies. The questions are about size of farm, proportion of rented area and size of irrigated area, the number of workers in the farm, machinery and greenhouse use and the frequency of agricultural extension visits. Moreover, questions are about amount of outputs and inputs for each kind of crop, specifically, amount of crop yield, size of cropping area, amount of fertilizer, pesticide, seeds and fuel, frequency of irrigation water use and method of irrigation.

The irrigation infrastructure and water use questions are to analyze factors of irrigation water efficiency. They are about source of water, satisfaction from the present water use, irrigation infrastructure possessed by farmers, participation to farmers group or water users' association, description of the farmer's group and annual cost of irrigation.

Since some farmers did not know how much water they consume in volumetric amount, the amount of irrigation water use was estimated based on irrigation design, method of irrigation, frequency and time of irrigation, size of cropping area, pressure of sprinklers and number of trees. In addition, size of canal and velocity of water flow in the canals was used for estimation of water use in Anjar. Irrigation water use per hour from canals in Anjar was estimated by width of the canals, depth of water in the canal and velocity of water flow in the canals. The width of canal is 35 cm and the depth of water in canal is 12 cm. The velocity of water flow in the canals which was measured by a flow meter on the 26th July, 2016 was 0.6 m per second or 0.7 m per second. Thus, the irrigation water use per hour was estimated as follows, $0.65(\text{velocity of water flow per second}) \times (0.35 \times 0.12)(\text{crosssectional area}) \times 60 \times 60 = 98.28m^3$.

4.4 Summary of Sample Data

This section shows summary statistics from the sample

4.4.1. Sample Characteristics

The sample size of interviewed farmers in the targeted areas was 155. It consists of 33 from Mchaytiyyeh, 41 from Anjar, 25 from Bcherre, and 54 from the Bekaa Valley.

The mean age of farmers in the sample is 52 years old. More than 60 percent of farmers are above 50 years old. The mean duration of formal education of farmers is 9.5 years. Most farmers have an educational background of primary education (31 percent). Farmers with higher education above secondary education are few (19 percent with secondary education and 17 percent with university or higher education).

The mean farm size is 4,916m^2 in Mchaytiyyeh, 37,816m^2 in Anjar, 9,412m^2 in Bcherre and 134,648m^2 in the Bekaa Valley. The irrigated area of farms in the Bekaa Valley is 84 percent and lower than that in other areas (100 percent in Mchaytiyyeh, 97 percent in Anjar and 98 percent in Bcherre). The proportion of rented areas of farms in Anjar and the Bekaa Valley (39 percent and 59 percent, respectively) are higher than the other regions (0 percent in Mchaytiyyeh and 13 percent in Bcherre) (Table 1).

Table 1. Mean farm size ($\boldsymbol{m^2}$) in each region

location	Observation	farm size	irrigated area	rented area
Mchaytiyyeh	33	4,914	4,914	0
Anjar	41	37,816	36,548	13,666
Bcherre	25	9,412	9,232	1,216
Bekaa Valley	54	134,648	113,204	80,037
sample total	155	59,540	51,705	31,695

In Mchaytiyyeh and Bcherre, the majority of farms are less than 1 hectare (86 percent and 68 percent, respectively), while in Anjar and the Bekaa Valley, most farms have more than 1 hectare in size (63 percent and 78 percent, respectively) (Table 2).

Table 2. Distribution of farm size in each region

Location	<0.5ha	0.5ha-1ha	1ha-5ha	5ha<	observation
Mchaytiyyeh	57%	29%	14%	0%	33
Anjar	10%	27%	41%	22%	41
Bcherre	52%	16%	32%	0%	25
Bekaa Valley	9%	13%	15%	63%	54
Sample total	27%	21%	25%	25%	

Some farmers use irrigation water from multiple water source. However, farmers in Anjar and Bcherre heavily depend on spring as water source while farmers in Bekaa Valley depend on well and farmers in Mchaytiyyeh depend on pond (Table 3). All farmers in Mchaytiyyeh and Bcherre and 90 percent in Anjar join farmers' group or water users' association while no farmers join such a group in Bekaa Valley. More than 90 percent of farmers in Mchaytiyyeh and Bcherre and Anjar answered they were satisfied with the present water supply while 65% of farmers in the Bekaa Valley did not. The farmers in Bekaa Valley were suffering from severe water shortage in their farms. This leads to higher proportion of unirrigated areas in their farms. Water source in each region.

Table 3. Water source in each region

	river	spring	Well	pond
Mchaytiyyeh	0	0	33	33
Anjar	3	35	12	1
Bcherre	0	25	0	0
Bekaa Valley	1	1	45	0
Total	4	61	92	36

4.4.2 Summary of Crop and Irrigation of Sample

Technical efficiency and irrigation water efficiency is based on data on outputs and inputs of each crops. Observations includes apple, pear, plum, peach, apricot and grapes as fruits tree, and pepper, eggplant, tomato, potato, onion, corn, cucumber, zucchini as vegetables. The sample consists of 167 fruits farms and 126 vegetable farms.

All farms in Mchaytiyyeh and Bcherre grow fruits only, specifically apple trees. The 70 percent farmers in Anjar and the 30 percent farmers in the Bekaa Valley grow fruits while the 29 percent farmers in Anjar and the 70 percent farmers in the Bekaa Valley grow vegetables. The 12 percent of farmers in Anjar, and 13 percent of farmers in Bekaa Valley grow both fruits and vegetable in their farm (Table 4).

Table 4. Cropping and location of sample

Fruits	Mchaytiyyeh	Anjar	Bcherre	Bekaa	Vegetable	Mchaytiyyeh	Anjar	Bcherre	Bekaa
apple	33	26	24	6	pepper	0	8	0	5
pear	0	7	3	2	eggplant	0	2	0	6
plum	0	17	1	10	tomato	0	4	0	10
peach	0	11	0	6	potato	0	2	0	17
apricot	0	1	0	4	onion	0	0	0	7
grape	0	0	0	11	corn	0	3	0	2
					cucumber	0	2	0	13
					zucchini	0	0	0	6
					parsley	0	2	0	6
Total	33	62	28	38	Total	0	23	0	72

Most farmers adopt drip irrigation for both fruit trees and vegetables to reduce wasted water. On the other hand, many farmers use furrow irrigation method for fruits (Table 4). This is because 92 percent of fruit farmers in Anjar are still heavily dependent on irrigation water supplied by canal systems from the spring. While methods of irrigation of fruit farms concentrate on surface irrigation and drip irrigation, those of vegetable farms are more various due to difference of characteristics of plants. Most potato and onion farmers adopts sprinklers, which no fruit farmers adopted (Table 4).

Table 5. Method of irrigation on each crop

Fruits	surface Irrigation	drip irrigation	micro sprinkler	sprinkler	Vegetable	surface irrigation	drip irrigation	micro sprinkler	sprinkler
apple	26	55	8	0	Pepper	6	4	2	0
pear	7	4	1	0	eggplant	2	6	0	0
plum	16	8	1	0	Tomato	2	11	0	0
peach	9	6	2	0	Potato	0	1	3	15
apricot	1	2	2	0	Onion	0	0	2	5
grape	0	10	0	0	Corn	2	1	2	0
					cucumber	1	13	1	0
					zucchini	0	5	1	0
					parsley	1	3	4	0
Total	59	85	14	0	Total	12	23	9	20

Table 6. Method of irrigation of fruits and vegetable farms on each region

	Fruits				Vegetables			
	surface irrigation	drip irrigation	micro sprinkler	sprinkler	surface irrigation	drip irrigation	micro sprinkler	sprinkler
Mchaytiyyeh	0	33	0	0	NA	NA	NA	NA
Anjar	57	2	3	0	13	2	4	2
Bcherre	1	18	8	0	NA	NA	NA	NA
Bekaa	1	32	3	0	1	42	11	18
total	59	85	14	0	14	44	15	20

Compared the amount of irrigation water application (m^3) per land (m^2) for fruits in each region, farmers in Anjar use much more amount of water than those in the other regions. This is because 92 percent of fruit farmers adopted surface irrigation from the canals. The amount of water application in Mchaytiyyeh is much less than any other region since WUA strictly controls applied amount by using flow meters on each farm plot.

Although most farmers in the Bekaa Valley adopted drip irrigation for vegetables, they applied more water than those in Anjar, who adopted surface irrigation. In Anjar, most farmers belong to farmers' group for irrigation water management. So, water use in Anjar is partly controlled and also knowledge of proper amount water use can be shared through the farmers' group. On the other hand, famers in the Bekaa Valley freely applied irrigation water. This can lead to much use of irrigation water.

Table 7. Mean irrigation water use (m^3) per land (m^2)

Fruits	Mchaytiyyeh	Anjar	Bcherre	Bekaa	Vegetable	Mchaytiyyeh	Anjar	Bcherre	Bekaa
apple	0.06	1.07	0.27	0.26	pepper	-	1.34	-	2.40
pear	-	0.98	0.03	0.20	eggplant	-	1.51	-	2.77
plum	-	1.09	0.10	0.49	tomato	-	1.72	-	3.15
peach	-	0.92	-	0.18	potato	-	0.89	-	2.16
apricot	-	0.09	-	0.09	onion	-	-	-	2.14
grape	-	-	-	0.24	corn	-	1.57	-	2.81
					cucumber	-	1.15	-	3.17
					zucchini	-	-	-	2.75
					parsley	-	1.31	-	1.39
Total	0.06	1.02	0.24	0.28	Total	-	1.39	-	2.55

CHAPTER 5

RESULTS AND DISCUSSIONS

This chapter summarizes the variables used in this study and presents the results of the estimation of parameters of production function and technical and irrigation water efficiency. This chapter also analyzes factors affecting the efficiencies and impact of cooperation among farmers on the efficiencies.

5.1. Stochastic Frontier Production Function Estimations

Table 8 presents a summary statistics of variables used in this study. Since fruits farms do not use seeds and green house, this research analyze technical efficiency and irrigation water efficiency separately in the two. Mean weight of seeds show large number because 19 farms among vegetable farms grow potatoes and its seeds are much heavier than any other vegetables. Compared with fruit farms, the mean size of cropping area per plot is bigger. This is because the most vegetable farms are in the Bekaa valley and the mean size of farms is bigger than any other regions. Vegetable farms put more inputs than fruit farms. In terms of irrigation water input, vegetable farm applied much more irrigation water. Although vegetables require more water than fruit trees, more water can be saved if there is irrigation water inefficiency.

The parameters estimated by ordinary least square (OLS) and stochastic frontier production function (SF) are presented in Table 9.

The coefficients of determination of fruits farm and vegetables farms show 0.803 and 0.947, respectively, and the coefficients of these production function estimated by OLS highly explain the production.

Table 8. Summary statistics of variables used

	Fruits (n=161)				Vegetables (n=95)			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
output (kg)	45,914	146,979	40	1,260,000	145,865	290,151	75	2,000,000
land (m^2)	13,835	29,795	50	280,000	34,893	68,197	50	400,000
water (m^3)	5,804	13,040	5	126,000	66,003	122,690	73	711,111
fertilizer (kg)	1,760	5,465	0	60,000	6,298	15,496	0	105,000
pesticide (kg)	67	354	0	4,234	2,139	13,256	0	120,000
seeds (g)	-	-	-	-	6,243,283	17,200,000	0	98,000,000
labor (person)	9	12	0	70	18	26	0	125
greenhouse (m^2)	-	-	-	-	288	1,480	0	13,500

Table 9. Estimated parameters by OLS and SF on Fruits and Vegetables

	Fruits (n=161)				Vegetables (n=95)			
	OLS		SF		OLS		SF	
	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std. Err	Coef.	Std. Err
constant	0.663	0.439	1.759 ***	0.395	-0.168	0.431	0.789	0.394
Ln(Land)	0.799 ***	0.066	0.718 ***	0.063	0.707 ***	0.130	0.593 ***	0.109
Ln(Water)	0.160 ***	0.056	0.207 ***	0.057	0.419 ***	0.121	0.493 ***	0.103
Ln(Fertilizer)	0.068	0.054	0.030	0.047	-0.011	0.058	-0.041	0.058
Fertilizer missing	0.519	0.325	0.362	0.291	-0.406	0.645	-0.832	0.632
Ln(Pesticide)	0.077	0.049	0.144 ***	0.046	-0.042	0.028	-0.016	0.022
Pesticide missing	0.161	0.316	0.173	0.291	-0.969 ***	0.392	-1.344 ***	0.361
Ln(Seed)	-	-	-	-	0.021	0.019	0.021	0.017
Seed missing	-	-	-	-	0.201	0.293	0.267	0.256
Ln(Labor)	-0.061	0.058	-0.061	0.062	-0.058	0.074	-0.023	0.068
Labor missing	0.218	0.782	-0.318	0.617	-0.262	0.322	-0.241	0.273
Ln(Greenhouse)	-	-	-	-	0.070 ***	0.030	0.063 ***	0.023
Region (dummy)	0.246	0.177	0.039	0.170	-	-	-	-
R-squared	0.803				0.947			
λ			1.970 ***	0.160			2.990 ***	0.214

*, **, *** significance at the 10%, 5% and 1% level, respectively

Estimations by SF consider existence of technical inefficiency in production, which those by OLS do not. Since this study adopts half-normal distribution as assumption of distribution of technical inefficiency, the null hypothesis is a single restriction involving a single parameter. In this case, the model estimated by method of maximum likelihood can be tested by using a simple z-test because unconstrained ML estimators are asymptotically normally distributed).

The null and alternative hypotheses are $H_0: \lambda = 0$ and $H_1: \lambda > 0$ and the test statistics is $z = \lambda/\mathrm{se}(\lambda) \sim N(0,1)$ where $\lambda = \sigma_v/\sigma_u$. The null hypothesis indicates there is no technical inefficiency. The test statistics of fruit farms is 1.970/ 0.160= 12.284 and that of vegetables farms is 2.990/ 0.214= 13.975. These exceed critical value $z_{0.95} = 1.645$, so the null hypotheses in both fruits farms and vegetable farms are rejected at the 5 percent of significance. This means that there exist technical inefficiencies in the sample. Thus, estimates by SF are more adequate that those by OLS.

All parameters but labor in both OLS and SF in fruits farms show positive signs while, in vegetable farms, coefficients of fertilizer, pesticide and labor show negative signs. The negative coefficient of labor in fruits farms can be explained by the fact that growing fruits does not constantly require labor force, compared with vegetables.

In fruit farms, size of land and amount of water significantly increase output in the OLS and SF. In addition, the amount of pesticide significantly increases the output in SF. In vegetable farms, size of land, amount of water and land for greenhouse significantly increase the output in both OLS and SF.

This study adopts Cobb-Douglas production function both in OLS and SF. The coefficients of each function means output elasticity. In the four production function, land was the most influential among inputs. This conforms to Adeyemo and Akinola (2010), Binam et al. (2004), and Belloumi and Matoussi (2006). Return to scale of production functions for fruits is increasing, while that for vegetable is decreasing.

5.2. Technical and Irrigation Water Efficiency

Table 10 presents mean technical efficiency (TE) and irrigation water efficiency (IE), and their distribution of fruits farms and vegetables farms.

The estimated mean technical efficiencies of fruit and vegetable farms are 62.90 percent and 60.87 percent, respectively. Technical efficiencies of fruits distribute more widely that those of vegetables. Minimum and maximum technical efficiency of fruit farms in the sample is 5.29 percent and 91. 64 percent while those of vegetable farms is 20.41 percent and 90.55 percent. The proportion of farms whose technical efficiency is below 50 percent is 21.12 percent in fruit farms and 26.32 percent. There does not exist difference of distribution tendency between fruit farm and vegetable farms.

The estimated mean irrigation water efficiencies of fruit and vegetable farms are 15.14 percent and 39.38 percent, respectively. These scores are much lower than those of the technical efficiency. The estimated mean irrigation water efficiency implies that the observed quantity of production could have been maintained by using observed amount of other inputs while reducing use of water by 84.86 percent in fruit farms and 60.62 percent. Both fruit farm and vegetable farms can save much water by improving efficiency.

Distribution of irrigation water efficiency of vegetable farms is wider than that of fruit farms, which is contrary to distribution of technical efficiency. Irrigation water efficiency of vegetable farms distribute from 3.68 percent to 81.07 percent while that of fruit farms distribute from 0.000042 percent to 64.77 percent. The proportion of irrigation water efficiencies below 20 percent is 62.73 percent of fruit farms while that of vegetable farm is 25.26 percent. Thus, irrigation water efficiencies of fruit farms can be raised more easily than those of vegetable farmers.

Table 10. Frequency distribution of efficiency

	Fruits		Vegetable	
Efficiency (%)	TE	IE	TE	IE
<20	5	101	0	24
20-30	5	44	13	8
30-40	8	7	8	17
40-50	16	7	4	9
50-60	24	1	15	12
60-70	28	1	15	16
70-80	61	0	18	8
80-90	13	0	21	1
>90	1	0	1	0
Observation	161	161	95	95
Mean	62.903	15.144	60.873	39.378
Minimum	5.294	0.000	20.407	3.679
Maximum	91.639	64.771	90.546	81.074

Table 11 presents factors affecting technical inefficiency and irrigation water efficiency in fruit farms and vegetable farms. In fruit farms, total irrigated significantly reduces technical inefficiency while adaption of surface irrigation significantly increases technical inefficiency. Participation to farmers' group and participation in maintenance of irrigation infrastructure reduce technical inefficiency, which is not significant at 10 percent level. In vegetable farms, age of farmers, years of schooling of household head and adoption of surface irrigation significantly and positively affect technical inefficiency. This conforms to Tegegne et al. (2014) and more aged farmers tend not to adopt new agricultural technology. Participation in farmers' group significantly reduces technical inefficiency. Their participation affects the efficiency most than any other factors.

The participation to farmers' group and size of total irrigated area significantly increase irrigation water efficiency in both fruits farms and vegetables farms. On the other hand, as expected, adoption of furrow irrigation significantly decrease water efficiency. In vegetable farms, age of farmers and years of schooling also significantly decrease water efficiency.

Table 11. Technical Inefficiency and irrigation water efficiency on fruits and vegetables

	Fruits (n=161)				Vegetables (n=95)			
	Technical Inefficiency		Water Efficiency		Technical Inefficiency		Water Efficiency	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
constant	0.390	0.916	-4.110 ***	0.817	-3.245 **	1.295	-0.996	0.841
Age	-0.010	0.012	0.018	0.011	0.031 **	0.015	-0.030 *	0.013
Schooling	-0.003	0.048	-0.005	0.042	0.129 **	0.056	-0.099 *	0.040
Surface irrigation	1.696 *	0.912	-2.169 ***	0.426	1.295 **	0.612	-2.552 ***	0.577
Farmers' group	-1.138	0.879	1.133 **	0.485	-1.298 *	0.713	1.356 *	0.549
Maintenance	-0.613	0.909	0.546	0.496	-	-	-	-
Total Irrigated Area	-0.007 *	0.004	0.006 **	0.003	-0.001	0.002	0.004 ***	0.001

*, **, *** significance at the 10%, 5% and 1% level, respectively

5.3. Efficiencies among Smallholders and Cooperation

Table 12 presents mean technical efficiency in each region of farm size group and Table 13 presents mean irrigation water efficiency in each region of farm size group. Technical efficiencies of vegetable farms increase as farm size increase while those of fruit farms do not. In fruit farms in Anjar and the Bekaa valley, mean technical efficiency whose farms size is above 5ha is much higher than any other size groups, however, among of farm size groups below 5ha, difference of mean technical efficiency is less than 5 percent point in Mchaytiyyeh, Anjar and the Bekaa valley though the size of total irrigated area significantly decreases technical inefficiency of fruit farms. Although difference of mean technical efficiency among farm size groups in Bcherre, is 8.92 percent point, technical efficiency is not affected by farm size so much among farm as long as farm sizes are less than 5 ha.

Among the four regions, mean technical efficiencies of Anajr, which has farmers group for irrigation water management, are the lowest than any other regions in farm size group below 5 ha. This can be attributed to irrigation method mainly used in the region. 92 percent of fruit farms in Anajar adopted surface irrigation and adoption of surface irrigation significantly increases technical inefficiency.

Mean technical efficiencies in Mchaytiyyeh and Bcherre are much higher than that of the Bekaa valley where there exist no farmers' group for irrigation water management. This mean cooperation in irrigation water management among farmers can affect technical efficiency positively without adoption of surface irrigation though participation of farmers' group was not significant to explain technical inefficiency in the sample.

In irrigation water efficiency, tendency is much the same as that of the technical efficiency. Technical efficiencies of vegetable farms increase as farm size increase while those of fruit farms do not, however, mean irrigation water efficiencies in both fruit and vegetable farms in the Bekaa valley increase as farm sizes increase. Though the size of total irrigated area significantly increases irrigation water efficiencies, irrigation water efficiencies in regions with farmers' group do not simply increase as farm size increase. Without farmers' group, smallholders are suffering from low irrigation efficiency. However, the coefficient of participation to farmers' group is much higher than that of total irrigates area. Participation to farmers' group contributes to increase of irrigation water efficiency of smallholders.

Compared with mean irrigation water efficiency of Anjar and the Bekaa valley, those of Mchaytiyyeh and Bcherre are much higher in fruit farms. In farm size group below 1 ha, mean irrigation efficiencies of Mchaytiyyeh and Bcherre are twice higher than those of Anjar and the Bekaa valley though 85 percent of farmers in Anjar, participate in farmers' group.

Participation to farmers' group significantly increases irrigation water efficiency while adoption of surface irrigation significantly decreases the efficiency. However, the adoption of surface irrigation affects irrigation water efficiency more than the participation to farmers' group because the coefficient of the participation is 1.13 and that of the adoption is -2.169 in fruit farms. The change from surface irrigation to other method of irrigation is inevitable in order to increase irrigation water efficiency.

Table 12. Mean technical efficiency of fruit and vegetable farms on farm size in each region

	Fruits (n=161)				Vegetable (n=95)			
Location	<0.5ha	0.5ha-1ha	1ha-5ha	5ha<	<0.5ha	0.5ha-1ha	1ha-5ha	5ha<
Mchaytiyyeh	75.39	77.01	72.53	NA	NA	NA	NA	NA
Anjar	53.80	51.67	51.26	84.26	47.67	59.92	82.28	76.42
Bcherre	68.19	77.11	69.26	NA	NA	NA	NA	NA
Bekaa Valley	60.75	59.10	61.61	72.15	56.81	55.57	64.14	67.96
Sample total	65.37	59.86	60.11	75.18	55.02	57.57	69.73	69.43
Observation (%)	40.37	31.68	22.98	4.97	48.42	13.68	13.68	24.21

Table 13. Mean irrigation water efficiency of fruit and vegetable farms on farm size in each region

	Fruits (n=161)				Vegetable (n=95)			
Location	<0.5ha	0.5ha-1ha	1ha-5ha	5ha<	<0.5ha	0.5ha-1ha	1ha-5ha	5ha<
Mchaytiyyeh	23.24	27.14	19.29	NA	NA	NA	NA	NA
Anjar	11.13	5.87	6.84	41.84	24.26	33.98	66.40	57.16
Bcherre	21.11	26.56	17.09	NA	NA	NA	NA	NA
Bekaa Valley	9.84	10.83	14.56	24.03	35.89	31.83	44.81	45.82
Sample total	23.95	8.52	21.22	13.83	33.61	32.82	51.45	47.79
Observation (%)	40.37	31.68	22.98	4.97	48.42	13.68	13.68	24.21

CHAPTER 6

CONCLUSION AND POLICY RECOMMENDATION

Mean technical efficiency of fruit farms and vegetable farms of sample areas in Lebanon were 62.90 percent and 60.87 percent, respectively. Mean irrigation water efficiency of fruit and vegetable farms of the sample in Lebanon is 15.14 percent and 39.38 percent. These results suggest that there is much room for improvement of crop production while maintaining the present inputs level just by improving technical efficiency and irrigation water efficiency.

The technical efficiencies of vegetable farms were apt to increase with the size of cropping area. However, in fruit farms, the size of farm does not affect technical efficiencies apparently though that affect irrigation efficiency in the Bekaa valley where no farmers belong to farmers' group for irrigation water management. This means that smallholders are suffering from low irrigation water efficiency without farmers' groups for irrigation water management.

In the regions with farmers' groups and water users' association, smallholders also show higher technical efficiency and irrigation water efficiency. However, adoption of surface irrigation significantly and greatly increases technical inefficiency. Thus, change of irrigation method from surface irrigation to other water saving irrigation method should be enhanced with enhancement of formation of farmers' group for irrigation water management

Lebanon does not have enough legal framework for farmers to organize water users' association or farmers' group with legal status. From the case of Mchaytiyyeh, the legal status of the farmers' group is important for financing and managing shared infrastructure. Policies to enhance farmers' group and associations are strongly required to increase technical efficiency and irrigation water efficiency of farmers, especially of smallholders. At the same time, policies to enhance water saving irrigation method, such as drip irrigation or micro sprinkler is also required, in place of surface irrigation.

APPENDIX 1

SURVEY QUESTIONNAIRE (ARABIC)

رقم الإستطلاع ___________________

أ- الأسئلة العامة

1- العمر ____________________________________

2- الجنس ذكر أو أنثى

3- أي مستوى أعلى تعليم لرأس المنزل؟

أ) أمّي

ب) التعليم الإبتدائي

ج) التعليم المتوسّط - عام أو مهني

د) التعليم الثانوي - عام أو مهني

ه) التعليم الجامعي

و) التعليم الفني/التقني العالي

ب - الأسئلة المتعلّقة بالمزرعة و الزّرعية

4- المكان ,القرية ____________________________________

5- مساحة المزرعة ____________________(الوحدة: ______________)

6- نسبة المساحة المؤجر من

المزرعة ____ %

7- مساحة المناطق المروية ____________________(الوحدة: ______________)

8- عدد العمّال الزراعين في المزرعة ____________________________________

9- هل تستخدم الآلات في المزرعة؟

نعم أو لا

إذا نعم, ماذا تستخدم؟ ____

____

10- كم دفيئة زراعية / خيمة (green house) عندك في المزرعة؟ __________________

ما هي مجموع المساحة المخصّصة للخيمة ؟ ________________________

(الوحدة: ____________)

11- هل تزور المعهد الزراعي؟

نعم أو لا

إذا نعم, كم مرة تزورها بالسنة؟______________________________________

12مسحة المنطقة المزروعة، والمنتجات المستعملية والمنتوج الزراعي، وطريقة الري

محصول		الوحدة	كانون الثاني	شباط	آذار	نيسان	أيار	حزيران	تموز	آب	أيلول	تشرين الأول	تشرين الثاني	كانون الأول	مجموع
1	مساحة الزراعة														
	ماء														
	مبيد الحشرات														
	سماد كيميائي														
	بزور ونبات														
	وقود														
	ساعات لشغل الفلاحة	ساعات بالشهر													
	ساعات لشغل الزرع	ساعات بالشهر													
	ساعات لشغل الحصاد	ساعات بالشهر													
	كمية المحصول														
	طريقة الريّ														

ج – الماء والوسيل ألريّ وأستخدم الماء ألريّ

13- أصل الماء وقدرتها

أ) نهر أو نبع قدرتها ________________ (الوحدة: __________)

ب) بئر قدرتها ________________ (الوحدة: __________)

ج) خزان قدرتها ________________ (الوحدة: __________)

د) بركة قدرتها ________________ (الوحدة: __________)

ه) غيرها ____________________________________

قدرتها ________________ الوحدة: __________)

14- هل موارد الماء الموجودة حاليّاً تكفي لتلبية الحاجة؟

نعم أو لا

15- ما نوع البنية التّحتية للريّ عندك بالمزرعة؟

____

____

____

16- هل تشترك بمؤسّسة مزارعين لإدارة ماء الريّ؟

نعم أو لا

إذا نعم, كم عضو فيها ؟ ____________________________________

إذا نعم, ما هي الخدمات المقدّمة؟

17- ما هي كمّية الماء التّي تتشاركونها ؟__________ (الوحدة: __________)

18- هل هناك قواعد لإستخدم ماء الريّ؟

نعم أو لا

إذا نعم, صفها

19- هل هناك عقاب لمخالفة قواعد إستخدام ماء الريّ ؟

نعم أو لا

إذا نعم, صفها؟

20- هل تشارك البنى التحتية للريّ مع مزارعين آخرين ؟

نعم أو لا

إذا نعم, ماذا تشارك؟

21 كم تكلفة تشغيل وصيانة البنى التحتية للري الخاصة بك؟

	الوحدة	كانون الثاني	شباط	آذار	نيسان	أيار	حزيران	تموز	آب	أيلول	تشرين الأول	تشرين الثاني	كانون الأول	مجموع
الكلفة المالية بالشهر														
ساعات الشغل بالشهر														

22 كم تكلفة تشغيل وصيانة البنى التحتية المشتركة للري؟

	الوحدة	كانون الثاني	شباط	آذار	نيسان	أيار	حزيران	تموز	آب	أيلول	تشرين الأول	تشرين الثاني	كانون الأول	مجموع
الكلفة المالية بالشهر														
ساعات الشغل بالشهر														

APPENDIX 2

SURVEY QUESTIONNAIRE (ENGLISH)

Questionnaire No.________________

I. General Questions

1. Age ____________________
2. Gender Male or Female
3. Highest Education of Household Head
   a.) Illiterate
   b.) Primary Education
   c.) Intermediate Education General or Vocational
   d.) Secondary Education General or Vocational
   e.) Higher School (University or more)
   f.) Vocational Training

II. Farm and Agriculture Related Questions

4. Location/Village ____
5. Size of Farm ______________________________(unit: ______________)
6. Share of Rented Land ____%
7. Size of Irrigated Areas ___________________________(unit: ______________)
8. Number of agriculture related workers in the farm____________________
9. Do you use machinery in your farm? Yes or No
   If Yes, what do you use at your farm?__________________________________
   ____
10. How many greenhouse do you use in your farm? ____________________
    How much is area of greenhouse?____________________(unit: ____________)
11. Do you visit agricultural extension? Yes or No
    If Yes, how often do you visit it in a year?____________________________
12. The amount of Cropping Area, Agricultural Inputs and Yield, and Method of Irrigation

Crop	Amount of	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Cropping Area														
	Water														
	Pesticide														
	Fertilizer														
	Seeds or seedling														
	Fuel														
	Tillage (working hour)	hour/month													
	Planting(working hour)	hour/month													

	Harvesting (working hour)	hour/month															
	Yield																
	Method of Irrigation																

Ⅲ. Irrigation Infrastructure and Water Use

13. Source of Water and Capacity

a.) River or spring Capacity ______ (unit: ______)

b.) Well Capacity ______ (unit: ______)

c.) Reservoir Capacity ______ (unit: ______)

d.) Pond Capacity ______ (unit: ______)

e.) Other (______)

Capacity ______ (unit: ______)

14. Present Water Resource meet water demand? Yes or No

15. What kind of irrigation infrastructure do you have?

______

______

______

16. Do you belong to water users' association or farmers' group for water management? Yes or No

If Yes, number of group member ______

If Yes, what services do the group offer?

______

______

______

17. How much do you use water shared by association/farmers' group?

______ (unit: ______)

18. Is there any rule for water use? Yes or No

If Yes, please describe it.

______

______

______

19. Is there any penalty for violation of water use rule? Yes or No

If Yes, please describe it.

______

______

______

20. Do you share irrigation infrastructure with members of association/group? Yes or No

If Yes, what infrastructure do you share?

____

____

____

21. How much is Operation & Maintenance cost of your own irrigation infrastructure?

	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Monetary Cost/month														
Working Hour/month	hour/month													

22. How much is Operation & Maintenance cost of shared irrigation infrastructure?

	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Monetary Cost/month														
Working Hour/month	hour/month													

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